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## Technical Memorandum

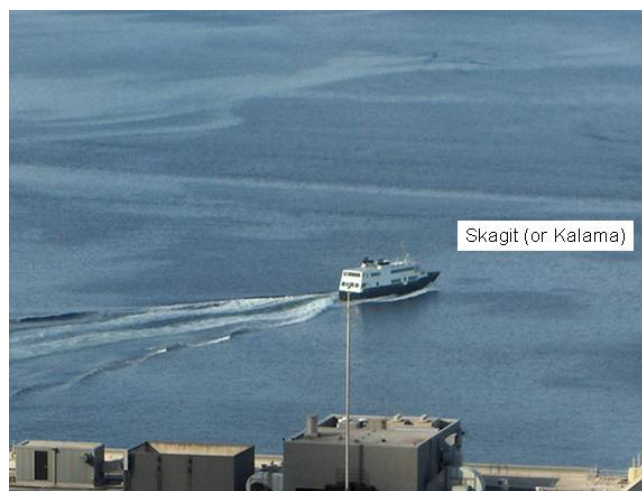
# Vashon Island/Downtown Seattle Ferry Route Service Enhancement Project - Wave, Propeller Scour, and Shoreline Analysis

## 1. Introduction

This technical memorandum documents the results of analysis conducted by Coast & Harbor Engineering, Inc. (CHE) to qualitatively evaluate the possible impacts of replacing the MV Skagit and MV Kalama with the MV Melissa Ann on the Vashon Island/Downtown Seattle route of the King County Water Taxi Passenger-Only Ferry and adding additional sailings to the existing service schedule.<sup>1</sup> The impacts considered under the analysis included vessel wake impact, propwash impact, and shoreline erosion impact. The following sections of this technical memorandum discuss the results of the analysis with regard to each of the above impacts.

## 2. Vessel Wake Impact Analysis

A vessel wake impact analysis was conducted based on comparison of wakes from the proposed Melissa Ann ferry to wakes generated by the currently operating passenger ferry Kalama or Skagit. Vessel wakes from currently operating vessels (Skagit or Kalama) are also referenced herein as existing conditions. Figure 1 shows vessel wakes generated by Skagit (or Kalama)<sup>2</sup> while leaving the Seattle terminal for Vashon Island.



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<sup>1</sup>Study performed under Work Order Contract Agreement E00144E08 with CH2M HILL, dated August 16, 2009.

<sup>2</sup> Skagit and Kalama are identical vessels, and it was not possible to determine which of them is in the picture.

### Figure 1. Passenger-only ferry leaving Seattle Terminal for Vashon Island

Because there were no direct wake measurements available for the Skagit and Melissa Ann ferries at the time of the study, a proxy method was used to develop a vessel wake database for each of these ferries. Proxy vessels with measured or computed vessel wake parameters were identified that have similar dimensions and hull configuration to the Skagit and Melissa Ann ferries. MV San Francisco wake data are from field measurements, and MV Harbor Bay Express wake data are from computer modeled data based on Computational Fluid Dynamics using software code SHIPFLOW. Data were from the Water Emergency Transportation Authority (formerly Water Transit Authority) in San Francisco. Table 1 compares parameters of proxy vessels selected for the analysis to those for the actual vessels.

**Table 1. Vessel Specifications**

Vessel	Hull Type	Length Overall (ft)	Beam (ft)	Draft (ft)	Service Speed (kts)
<b>Skagit</b>	Monohull	112	25	8.0	25
<b>San Francisco</b>	Monohull	169	34	6.0	20
<b>Melissa Ann</b>	Catamaran	77	30	5.0	28
<b>Harbor Bay Express</b>	Catamaran	72	23	4.0	25

Figure 2 shows the actual vessels and proxy vessels used in the analysis. The MV Melissa Ann initially operated in the early 1990s as a U.S. Army fast ferry at Kwajalein Island under the vessel name Jelang K. Please note that MV Skagit is smaller in length, deeper in draft, and faster in speed than the selected proxy MV San Francisco. Each of these parameters (speed, length, and draft) affects the formation of vessel wakes differently. For example: higher vessel speed for sub-critical flow conditions generates larger wave heights; smaller vessel draft generates smaller wave heights; and longer vessel length may generate larger wave periods. Due to differences in these parameters, there is no standard procedure or engineering method that provides a reliable adjustment to wake parameters from proxy vessel to prototype. However, it is likely that the difference in speed and draft would result in underestimates of wake wash from MV San Francisco. In other words, wakes from MV Skagit are likely larger than those from MV San Francisco.

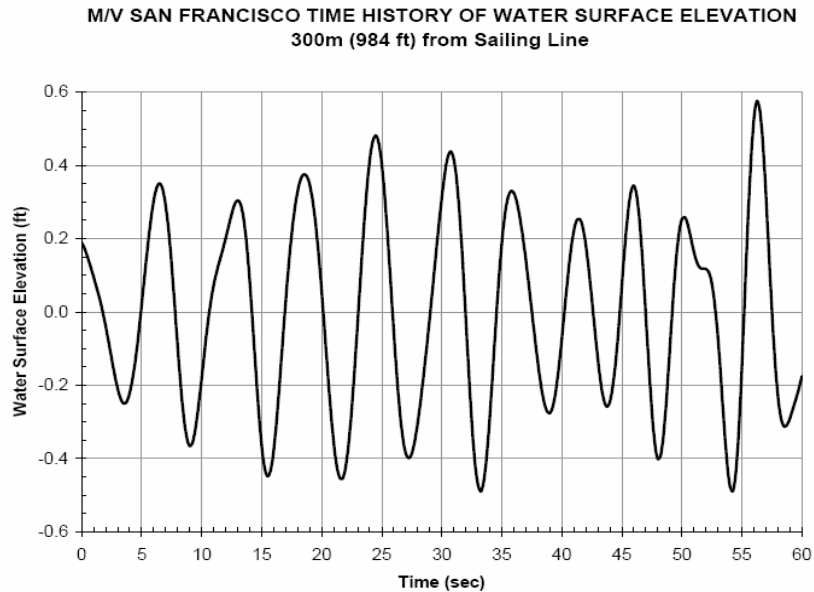
On the other hand, MV Melissa Ann is a slightly larger vessel (by length and draft) and has a higher speed than the proxy vessel Harbor Bay Express. It is likely that wakes from Melissa Ann are slightly larger than those from Harbor Bay Express. For the comparison analysis, it was assumed that the differences in the estimate of wakes for Skagit and Melissa Ann from those for the proxy vessels are equal; and thus, do not affect the comparison results.



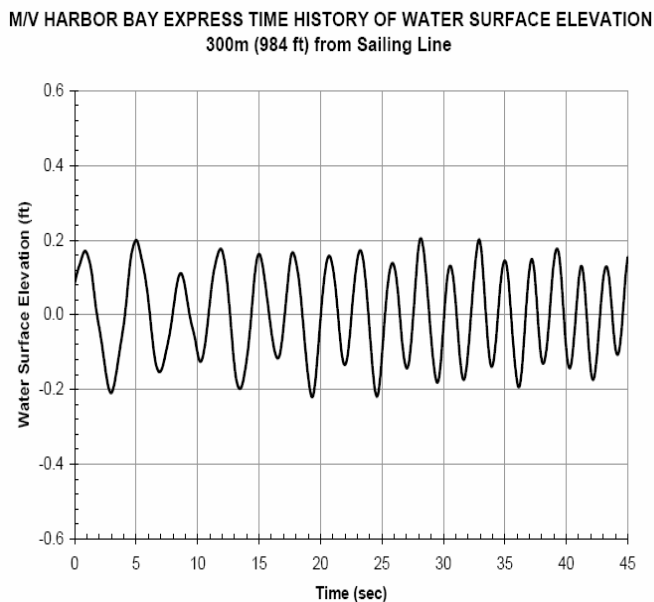
**Figure 2. Study vessels (Skagit and Melissa Ann) and proxy vessels (San Francisco and Harbor Bay Express)**

A time series of available water surface elevations (vessel wakes) from the proxy vessels were used to approximate a time series of water surface elevations for the Skagit and Melissa Ann ferries. Figure 3 shows vessel wakes (time series of water surface elevation) from the proxy vessel MV San Francisco that will be used for further analysis as the Skagit ferry wake. Figure 4 shows the vessel wake from the MV Harbor Express that will be used as the Melissa Ann ferry wake.

A comparison analysis between vessel wakes from two different ferries was conducted using recommendations from *Wake Wash Measurement Protocol* (CHE, 2007). The highest waves in a wave train were selected from each ferry, and wave heights and wave energy were compared separately.

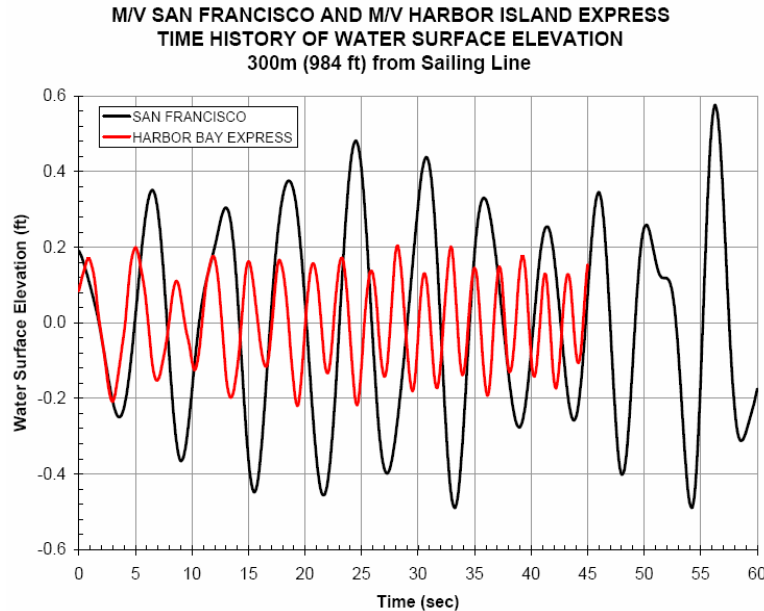


**Figure 3. Time history of water surface elevation from MV San Francisco wake to be used to describe wake wash from Skagit ferry**



**Figure 4. Time history of water surface elevation from MV Harbor Bay Express wake to be used to describe wake wash from Melissa Ann ferry**

Figure 5 shows a comparison of time history of water surface elevations for MV San Francisco and MV Harbor Bay Express at a distance of 300 m (984 ft) normal to the sailing line (direction of travel by the vessel).



**Figure 5. Comparison of time history of water surface elevation for MV San Francisco and MV Harbor Bay Express**

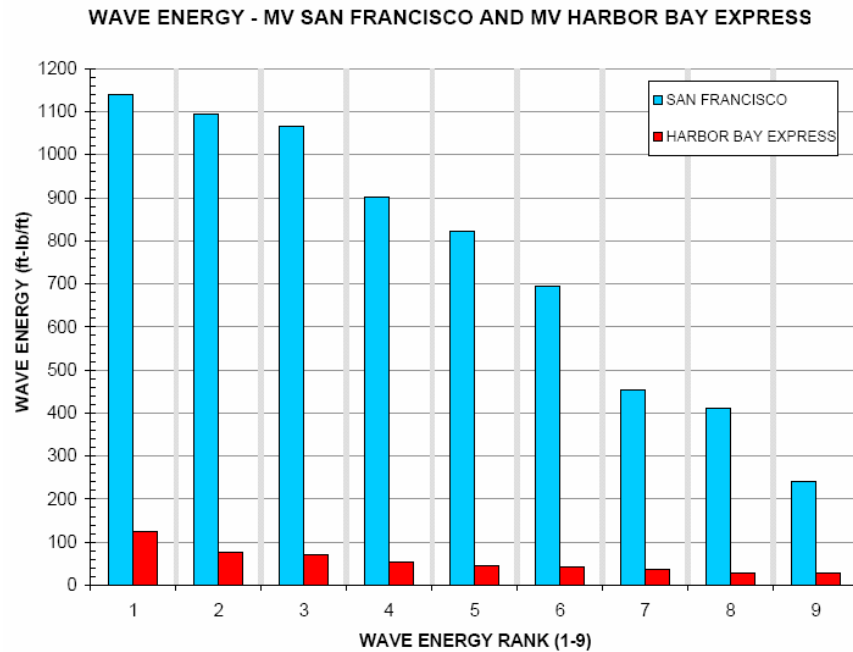
Figure 6 shows a comparison of the energy for the nine waves from each vessel having the greatest energy from the wave records shown in Figures 3 and 4 above. The Y-axis shows the total wave energy in ft-lb/ft, and is the total energy for every 1-ft width of the wave along the wave crest. The X-axis shows the descending order of rank of the nine waves having the highest energy for each vessel<sup>3</sup>. For example, Wave Energy Rank 1 is the wave having the highest energy for each vessel (approximately 1140 ft-lb/ft for MV San Francisco and 130 ft-lb/ft for MV Harbor Bay Express). The wave energy for MV Harbor Bay Express is approximately 10 percent of the wave energy for MV San Francisco.

Based on the analysis, it was concluded that:

- Vessel wakes generated by Melissa Ann are smaller in height and period than those currently produced by Skagit.
- Melissa Ann vessel wake energy transmitted into the water column (computed with regard to Wake Wash Measurement Protocol) is smaller than that transmitted by Skagit (approximately 10 percent the energy of Skagit).
- The probability of vessel wake impact from Melissa Ann on the ambient aquatic environment would be smaller than that from the existing Skagit ferry vessel.
- The analysis in this report is limited to a qualitative comparison of the ferries Skagit and Melissa Ann. Measured wake waves from the Melissa Ann are required for any

<sup>3</sup> Based on previous studies (CHE 2007), it was determined that major effects on shoreline and bottom erosion typically occur from the first largest nine waves in a wake train. These nine waves are recommended for consideration of possible impact analysis from vessel wakes.

quantitative analysis. The computer model generated data is not applicable to other situations and conditions.



**Figure 6. Comparison of wake wave energy**

### 3. Propwash Impact Analysis

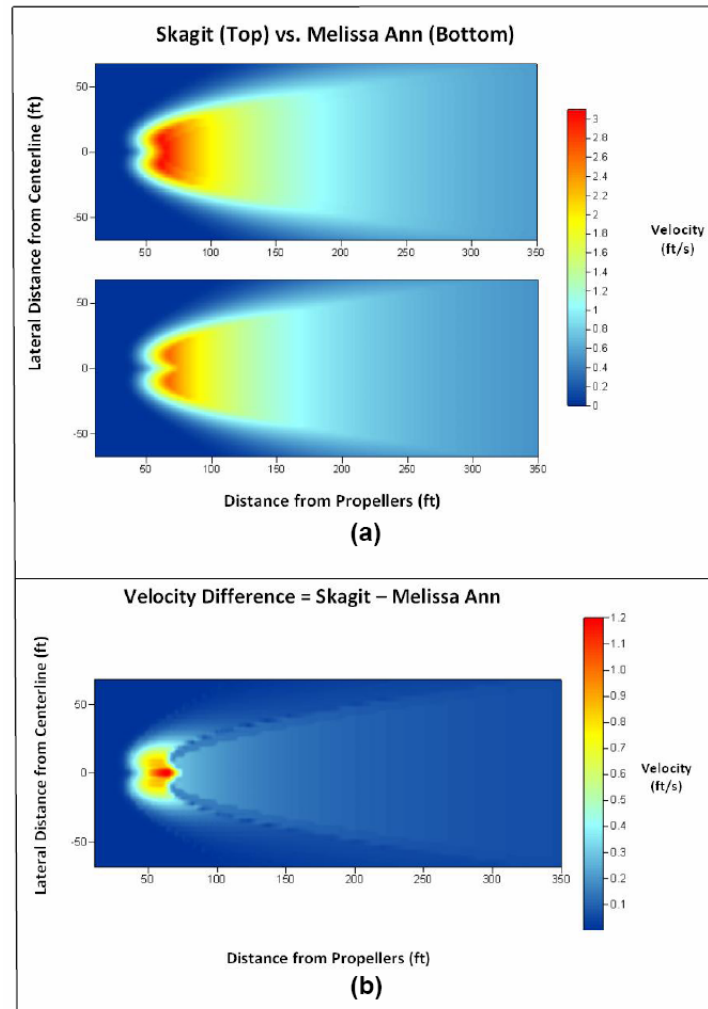
A propwash analysis was conducted based on numerical modeling of propeller current velocity fields for Skagit and Melissa Ann. Table 2 shows the principal vessel parameters and the depths used for the analysis. The modeling also took into account a number of other inputs, including the angle of the propeller shafts to the water surface. The maneuvering RPMs in the table are based on power settings used for maneuvering in the vicinity of the Vashon dock, furnished by King County.

**Table 2. Vessel Specifications**

Parameter	MV Skagit	MV Melissa Ann
No. Engines	4	2
No. Propellers	4	2
HP each Engine	999	1,400
Propeller Dia. (ft)	3.83	3.083
Water Depth (ft)	30.0	30.0
Depth Below Propeller Axis (ft)	24.6	25.7
Maneuvering RPM	332	350

Modeling results for propwash in plan view for a 30-ft water depth are shown in Figure 7. Figure 7(a) shows the plan view of velocity fields behind the propellers for both vessels approximately 0.9 ft above the seabed. The color scale shows the gradation of water

velocities, with blue being the lowest (0.0 ft/sec darkest blue) to red being the highest (3.0 ft/sec). Skagit propwash not only has a larger footprint than that for Melissa Ann, but the propwash velocities are higher, as indicated by the color shading. Figure 7(b) shows the difference in velocity (Skagit velocity – Melissa Ann velocity) on the harbor bottom. The color scale indicates the difference in velocities 0.2 ft/sec (blue) to 1.2 ft/sec (red). It is clearly shown that Skagit velocities are higher than velocities for Melissa Ann.



**Figure 7. Modeled propwash velocities for Skagit and Melissa Ann (a) and velocity differences (b)**

Based on numerical modeling and analysis, the following summarizes our findings regarding Melissa Ann's possible propwash impact:

- Propwash velocities generated by Melissa Ann's propulsion system are smaller than those from Skagit.
- Melissa Ann's propulsion system will likely create less impact on bottom sediment (scour and re-suspension) than the existing vessel (Skagit).

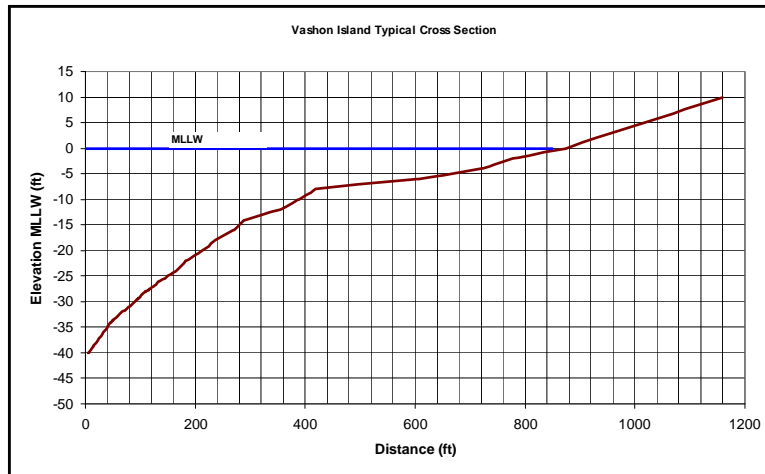
#### 4. Shoreline Erosion Impact Analysis

CHE analyzed the possible shoreline erosion impact from the ferry, based on analysis of vessel wake run-up at the Vashon Island shoreline. Nearshore and beach topographic data were readily available for the Vashon site, and the location would be subject to wakes generated fairly close to the shoreline. Runup heights would be higher for Skagit compared to Melissa Ann's run-up, regardless of where the shoreline run-up analysis was performed; so other sites were not analyzed for this qualitative assessment of wakes. It is suggested that a higher elevation of run-up corresponds to a larger rate of erosion and shoreline recession. An evaluation of vessel wake run-up was conducted for the shoreline that is typically exposed to vessel wakes. This location is found to be on the north side of Vashon Island adjacent to the ferry terminal. Figure 8 shows the location of the cross-section at the shoreline that was used for run-up analysis.



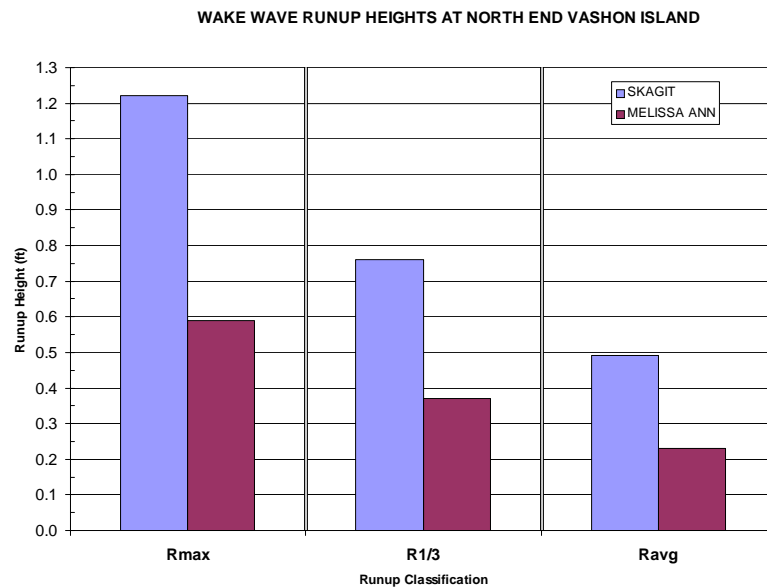
**Figure 8. Shore profile location**

The bathymetric-topographic survey data at the selected shoreline was compiled from previous CHE studies. Bottom and beach elevations were extracted along the cross-section, perpendicular to the shoreline and adjacent to the passenger ferry terminal. Figure 9 shows bottom elevations along the cross-section.



**Figure 9. Vashon Island, north shoreline, typical beach and bottom slope cross-section**

Computations of run-ups from ferry wakes was conducted using a standard methodology from the *Coastal Engineering Manual*, U.S. Army Corps of Engineers (USACE, 2006). Vessel wake parameters, heights and period, developed for the Skagit and Melissa Ann ferries (see Section 2), were used as input for run-up computations. The results of calculations are shown graphically in Figure 10.



**Figure 10. Vashon Island shoreline run-up height computations from Skagit (blue) and Melissa Ann (magenta) ferry wakes<sup>4</sup>**

<sup>4</sup> Input parameters for computations of run-ups include significant uncertainties and assumptions. The results of computations are to be used for comparison analysis only, and are not valid for any other application.

The figure shows run-up heights (distance measured vertically from the stillwater surface) for three standard wave components of vessel wakes:  $R_{\max}$  (maximum wave run-up);  $R_{1/3}$  (average of the highest third of the run-ups); and  $R_{\text{avg}}$  (average wave run-up). For all three components, the existing run-ups on the Vashon Island shoreline generated by the Skagit ferry are larger than run-ups that would be generated by the proposed Melissa Ann ferry wake.

Based on the above analysis it was concluded that:

- Vessel wakes generated by Melissa Ann would result in smaller run-ups on the shoreline than the existing ferry Skagit due to less wake height, period, and energy.
- The probability of adverse impact on the shoreline from Melissa Ann would be smaller than from the existing ferry Skagit.

## 5. Summary

CHE has completed qualitative analysis of propwash, vessel wakes, and shoreline erosion to evaluate possible impacts of replacing the MV Skagit and Kalama with the MV Melissa Ann passenger-only ferry on the Vashon Island/Downtown Seattle route. CHE has concluded the following:

- The probability of vessel wake impact from Melissa Ann on the ambient aquatic environment would be smaller than that from the existing ferry Skagit.
- Melissa Ann's propulsion system will likely create less impact on bottom sediment (scour and re-suspension) due to less propwash velocity than the existing vessel Skagit.
- The probability of adverse impact on the shoreline from Melissa Ann would be less due to smaller run-up heights than from the existing ferry Skagit.

## 6. References

CHE. 2007. *Wake Wash Measurement Protocol*. Prepared by Coast & Harbor Engineering for Water Transit Authority (now Water Emergency Transportation Authority), San Francisco, CA.

USACE. 2006. *Coastal Engineering Manual (EM 1110-2-1100)*. U.S. Army Corps of Engineers, Department of the Army, Washington, D.C.